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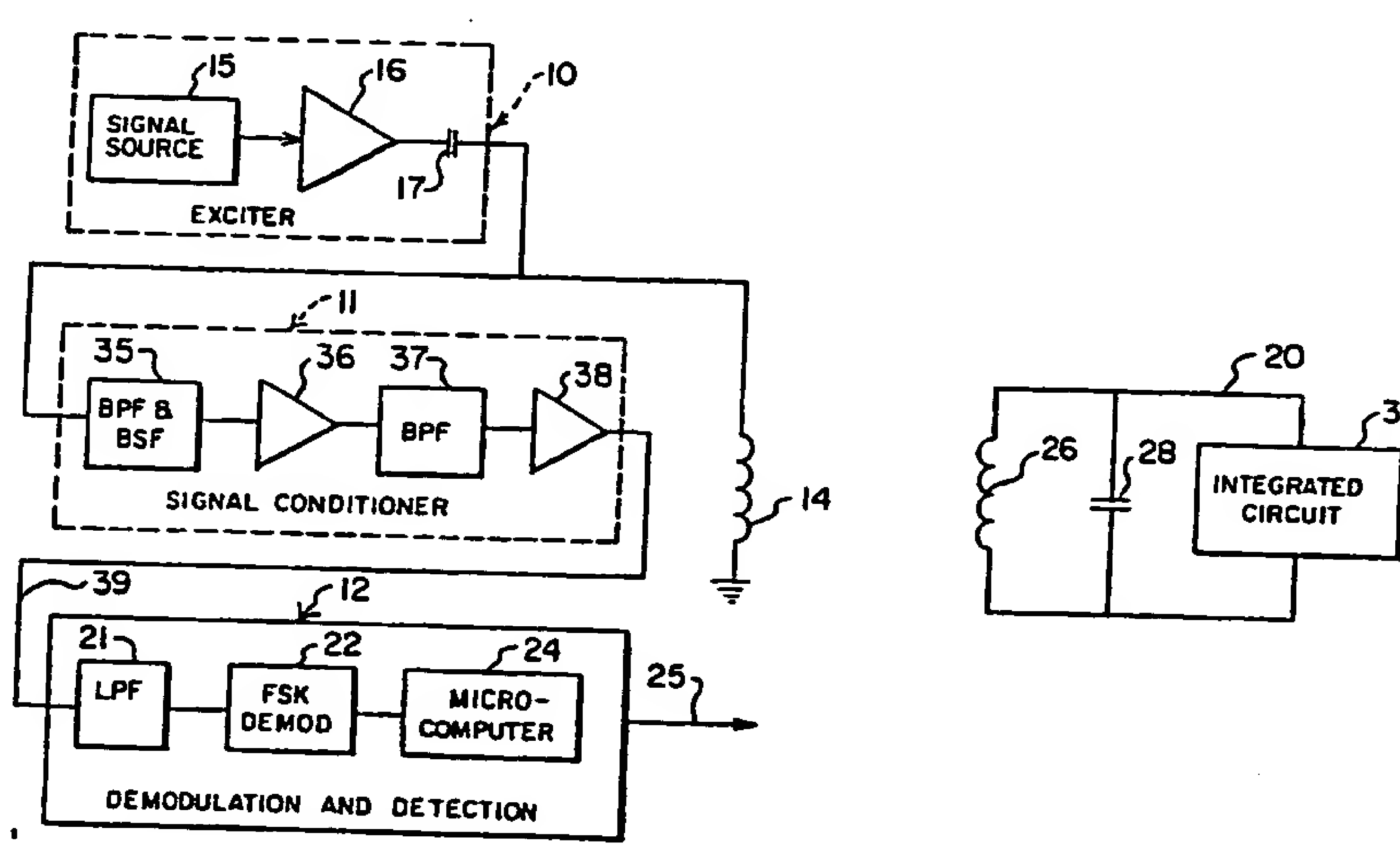

(57) Abstract

Electronic transponders (20) embedded within or on vehicle tires (40) are electromagnetically actuated by signals from an interrogator coil (14). The transponder includes a receiver/transmitter coil (26) of one or more loops of wire (54) strategically placed along the sidewall or in proximity to the tread face of the tire. The transponder responds to actuation by producing a shifted frequency modulated with synchronization pulses and unique device identifying digital information. The transponder data stream can also include information on the condition and environment of the tire. By appropriate placement of the tire transponder coils and the interrogator coils, dynamic reading of the tire data is possible even with the vehicle in motion.

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Description

Vehicle Tire Identification Syst m

Technical Field

The present invention relates to apparatus and methods of automatically identifying vehicle tires. More particularly, the present invention relates to systems including passive transponders which respond to interrogation by an electromagnetic field at radio frequencies (RF) by returning a digitally encoded signal which uniquely identifies the interrogated device. While not necessarily limited thereto, the present invention is especially useful for dynamically identifying vehicle tires of all kinds and in widely varying environments.

Backgound Art

For many years vehicle tires were identified through serial numbers stamped on their sidewalls. Difficulty in reading those numbers automatically and the ease with which the numbers are obliterated has caused interest to evolve towards some form of automatic system. For instance, U.S. Patent 2,920,674 to Bull molded magnetizable strips into the bead of the tire with digital magnetic encoding on those strips intended for detection by a magnetic field detector.

Another configuration of magnetic material in a coded structure is shown in U.S. Patent 3,233,647 by Newell which selectively removes portions of electromagnetic material to establish a digital code on a magnetic strip embedded into the tire. Unfortunately such devices are subject to loss of the magnetic field generator during normal use of the tire. Worse, they require the user to locate the magnetic strips and then to move the magnetic detector over the code elements in such a way as to detect the indicia the magnetic fields represent.

Earlier attempts to use inductively coupled RF identification systems in tires utilized transponders which were developed for general purpose identification of objects, animals, or persons. These transponders were small in size, ranging from an .083" diameter x 1/2" long injectable transponder, to a transponder 4" x 5" x 1" in size. Some transponders were limited in range such as about 1.5 feet. When such a transponder was embedded or placed in the tire, it was necessary to physically move the interrogator coil around the periphery of the tire in order to locate the transponder.

Advances in technology have made it possible to produce relatively small, integrated circuit chips which respond to an interrogation signal at their receiving antenna to produce a digitally encoded response signal. Earlier versions required a battery or other independent source of power which rendered them unacceptable for tire usage particularly in view of the hostile environment in which they must function. Thus interest turned to development of passive transponders.

A particularly attractive arrangement of a passive identification transponder is taught in commonly assigned U.S. Patent 4,730,188 by Milheiser. By attaching such a transponder to the sidewall or even to the inner wall of a tire, it is possible to produce a recognizable identification signal by passing an interrogator/receiver wand over the tire until it is in proximity to the location of the transponder. While this is a marked improvement over the prior art, it still requires the user to locate the transponder element that is in or on the tire by moving the wand around the tire perimeter. This makes it difficult to identify the individual tires in a stack and makes it extremely difficult to dynamically sample identification data as the tires mounted on a vehicle are moving past a reading station.

In order to use a tire transponder with an interrogator coil buried in the roadway, it was necessary to have an interrogator coil of a dimension, in the direction of travel, larger than the circumference of the tire so that the transponder passes in

close proximity to the ground at some point within the interrogator coil. Then, if dual wheels or tandem axles were used, multiple transponders might respond at the sam time to th same interrogation signal.

Other transponder-interrogator systems having longer reading range have the disadvantage that tires stacked in close proximity in a warehouse, or dual tires on trucks defy satisfactory identification on an individual basis, because of the problem of multiple transponders responding at the same time to the same interrogation signal.

Disclosure of the Invention

A primary object of the invention is to provide a system for identifying a tire consisting of two units. One is a passive transponder embedded in the tire to respond to interrogation with a unique identifying code. The other unit is a separate interrogator-reader which is advantageously configured to interface with the transponders.

The transponder consists of a coil of wire embedded in the periphery of the tire. The coil is coupled to an electronic circuit. The transponder is preferably powered from the interrogating unit by way of inductive coupling. The transponder produces a signal which is fed back through the inductive coupling to the interrogator unit. This signal may contain any combination of static and/or dynamic data such as the identification number of the tire, the temperature and pressure of the tire and/or its environment, etc..

A relatively small interrogator coil placed anywhere around the periphery of the tire can cause the transponder to respond. The coupling between interrogator coil and transponder coil is controllable so that the transponders in adjacent tires (eg: in dual wheels, tandem axles, or in warehouse stacks) do not respond in a manner which would cause difficulty in obtaining individual tire identification.

In accordance with one feature of this invention, an interrogator coil is located in such a way that individual tires are identifiable without interference from other tire transponders in the vicinity. As is apparent from the subsequent detailed description, it is possible to obtain this result by embedding the coil in a roadway. By proper placement of the coil with respect to the path of vehicle travel, it is possible to sequentially detect individual tires on a moving vehicle.

The apparatus for electronically identifying vehicle tires in accordance with this invention includes a coil of at least one conductive wire loop which is attached to a signal generator. The signal generator responds to the presence of predetermined signals at the coil by transmitting a signal encoded with information uniquely identifying the signal generator. These elements are positioned relative to the sidewall and/or tread surfaces of a vehicle tire by securing both the coil and the signal generator to the tire with the coil positioned so that its loop is in a relatively constant relationship relative to one of the tire surfaces.

The coil becomes energized whenever the predetermined signal is produced and brought into proximity to the tire surface or surfaces which have the coil secured with respect thereto. Data relative to the tire is acquired by detecting the encoded signal transmitted from the signal generator.

A second coil external to the tire can receive the encoded signal transmitted from the signal generator and concurrently introduce the received signals to the encoded signal detector. This second coil can function as a dynamic interrogator by placing it in a position in a path of travel of vehicles having tires with transponders incorporated therein. Further, by configuring this interrogator or second coil with spaced, generally parallel edges oriented at an angle relative to the dir ction of travel of the tire along its path of travel, it is possible to read data from a multiplicity of tires on that vehicle without interference between the transponders. Thus it

is possible in accordance with this invention to dynamically retrieve the encoded signal transmissions.

Preferably the transponder coil, when positioned under the tread surface of the tire, is oriented with sufficient spacing from the tire tread so that the tread itself will wear away before the coil is exposed.

Still further, it is possible to accommodate output signals from condition sensors associated with the tire. The signal generator can respond to these sensors by transmitting encoded information corresponding to the sensed tire condition or conditions in addition to the other information which uniquely identifies the signal generator. Note that the signal generator can transmit the encoded signals by introducing them to the same coil that is energized by the predetermined signal.

With the predetermined signal at a first frequency, the signal generator means can convert this predetermined signal to a different frequency for the encoded signal transmission. This makes it possible to concurrently transmit the encoded signal while receiving the predetermined signal.

Preferably the coil and the signal generator are embedded in the tire with the coil in spaced relation to the tire bead in the inner periphery thereof. While data communication is facilitated by positioning the coil under the tread surface of the tire, it should have sufficient spacing therefrom so that the tire tread will wear away before the coil is exposed.

Those having normal skill in the art will recognize the foregoing and other objects, features, advantages and applications of the present invention from the following more detailed description of the preferred embodiments as illustrated in the accompanying drawings.

Brief Description of the Drawings

FIG. 1 is a block diagram of the system including a reader/exciter unit and a passive integrated transponder (PIT) unit.

FIG. 2 is a side view of a vehicle tire showing the general relationship of one transponder coil wire.

FIGS. 3 and 4 are cross-sectional views of vehicle tires showing several possible locations of transponder coil wires.

FIG. 5 is a schematic view of a multiple turn transponder wire and the integrated circuit with which it interacts.

FIG. 6 is a plan view showing the relationship of vehicle tires with regard to interrogator coils.

Best Mode for Carrying Out the Invention

FIG. 1 illustrates in block diagram form the overall operative interrelationships between the electronic components preferably utilized by the present invention. For the interrogator/detector, these include an exciter circuit 10, a signal processing conditioner 11, and a demodulator/detector unit 12 all of which are coupled to the transmitting interrogator coil 14.

The three main functional units of the reader/exciter unit includes the exciter 10, a signal conditioner 11 and the demodulation and detection circuits 12. The exciter 10 consists of an AC signal source 15, followed by a power driver 16 which provides a high current, high voltage excitation signal to the interrogator coil 14 through a capacitor 17. The interrogator coil 14 and the capacitor 17 are selected to resonate at the excitation signal frequency so that the voltage across the coil is much greater than the voltage output from the driver 16.

The signal conditioner 11 connects to the interrogator coil 14 and serves to amplify the identification signal returned from the transponder 20 while filtering out the excitation signal frequency as well as other noise and undesired signals outside of the frequency range used by the transponder signals.

The amplified output of the signal conditioner 11 is fed to the demodulation and detection unit 12 which includes a low pass filter 21 to further reduce excitation signal energy, a frequency shift keyed (FSK) demodulator 22 and a microcomputer 24. The FSK demodulator 22 is a phase-locked loop circuit configured as a tone decoder which gives a digital output as the signal from the transponder 20 shifts between two frequencies. Microcomputer 24 extracts the identification code from this digital output by observing the timing of transitions between the two logic levels.

The identification code obtained by the microcomputer 24 is transferred from output 25 to any of a variety of output devices as desired. Some examples are displays or printers, communication lines coupled to a remote point, tapes, disks or other storage medium, another computer, and so forth.

The transponder 20 consists of an induction coil 26, an integrated circuit 30 and an optional resonating capacitor 28. Induction coil 26 is located such that the magnetic flux generated by the interrogator coil 14 couples energy at the exciter frequency into the transponder. The integrated circuit contains power conversion, frequency conversion, logic, counter and memory circuits which generate a coded signal containing the identification number. This signal is returned to the induction coil 26 and to the interrogator coil 14 via inductive coupling.

Integrated circuit 30 is powered by the signal received from the interrogator coil 14. It also shifts the received signal frequency so that a return signal is transmitted from coil 26 at the same time the interrogator is continuously transmitting its basic frequency. The power converted in circuit 30 drives

its logic so as to digitally encode the return signal with intelligence corresponding to the identification of the tire in which transponder 20 is located.

The signal returned by transponder 20 typically will include trains of bits usually starting with synchronization blocks followed by a series of bits that specify the identity of the transponder 20 and thus the identity of the tire with which it is associated. Note that it is possible to include suitable sensors strategically placed in or around the tire to add data fields to the information retuned to the interrogator and detector 12. Details of one way of implementing the functions for circuit 30 are shown in Milheiser Patent 4,730,188.

The signal conditioning network 11 in the interrogator unit includes a series of filters 35 and 37 interconnected with amplifier stages 36 and 38. This provides a band pass function correlated to the shifted frequency produced by transducer 20 to allow that frequency to pass to network output 39 while concurrently blocking the continuous interrogation frequency from exciter 10 and noise from the input to demodulator and detection network 12.

Network 12 employs a low pass filter 21 followed by a frequency shift keyed demodulator 22 so that microcomputer 24 essentially receives the intelligence originated by the integrated circuit 30 of transponder 20.

A typical vehicle tire 40 is shown in FIG. 2. Its inner circumference is reinforced by a bead 41 which is a closed loop of wire. The sensitivity of the transponder coil 44 is adversely effected if it is too close to bead 41. Conversely, the tread face 42 is subject to wear and therefore it is important to locate the coil 44 away from the wear hazard of tread 42. Three possible locations 44A, 44B and 44C are illustrated in the cross-sectional view of tire 40 in FIG. 3. That is, wire 44 can assume any of locations 44A or 44C on either side of the sidewall, 44B under the tread face 42, or in any combination of those positions.

Note that by placing transponder wire 44 centrally under the tread 42, the spacing between transponder wires in adjacent tires is optimized and identification of individual tires is enhanced. This is especially useful where the tires are stacked or mounted in dual or multiple wheel configurations.

FIG. 4 is a cross-section of another typical tire 45 with the radial reinforcement wires generally shown along with the bead 46. Five alternative locations for transponder wires are depicted in FIG. 4. Somewhat similarly to FIG. 3, wires 47A and/or 47B are embedded in the sidewall far enough from tread 48 so as not to interfere with recapping while minimizing exposure of wire 47 to road hazard damage.

Somewhat surprisingly, location of transponder wire at 50 inside the steel belts but near the inner surface of tire 45 is an acceptable location for the transponder coil. Location of the wires between layers of steel belts as at 51 is likewise acceptable as is location just outside of the belts as at 52. If tire 45 is constructed with wire 52 in the tread 48, it is important that adequate spacing is allowed to avoid damage from road wear or recapping.

Once again, the closer the wire is to the metal loop of central bead 46, the more the RF communication sensitivity is reduced even though bead 46 is not normally grounded. The array of steel reinforcing strands typically present in a steel belted radial tire are generally illustrated in FIG. 4. It was found that location of the transponder coil in close proximity to these tire belts and even in electrical contact with them does not significantly disturb the electromagnetic communication between the interrogator and the transponder. Perhaps this is because the steel reinforcing belts of the tire are electrically floating and insulated from bead 46.

FIG. 5 is a schematic of a typical tire transponder but without the tire. Transponder coil 54 is formed of one or more turns (three are shown in FIG. 5) of insulated wire or bare wire separated by insulating rubber in the manufacturing process.

Acceptable materials for the wire include steel, aluminum, copper or other electrically conducting wire. The wire diameter is not generally considered critical for operation as a transducer. For durability, stranded steel wire consisting of multiple strands of fine wire is preferred. Other wire options available include ribbon cable, flexible circuits, conductive film, conductive rubber etc.

The integrated circuit of electronic module 55 is packaged or mounted on a circuit board or substrate providing for attachment of the transponder coil wires 54 by any suitable means including welding, soldering, bonding or suitable cement. The assembly of coil 54 and module 55 as shown in FIG. 5 is as it might appear just before it is implanted in the mold for the fabrication of the complete tire. An alternative is to wind the transponder coil as part of, or during, the tire fabrication process.

The type of wire and number of loops in the coil for the transponder is a function of the anticipated environment of tire use and the preferred distance of interrogator communication. While in a typical truck tire, six loops of thirty gauge copper wire operated satisfactorily, copper may have a somewhat greater tendency to break from the repetitive stresses associated with normal tire use. Thus other material more tolerant of flexing and tire usage environments such as steel may prove more desirable for the coil wires in some applications.

The greater the number of loops of the transponder coil, the greater the distance of successful interrogation of a given tire transponder. Conversely, the greater the distance of interrogation, the more difficult it is to differentiate between responses from particular tires. It was found that use of six loops embedded in the sidewall of a truck tire just below the tread produced signals that could differentiate betw n tires relative to a hand wand interrogator even when the tires were stacked or in dual mounting relationships.

In use, a system in accordance with this invention employs an interrogator coil 14 formed as a loop in an assembly that is brought into proximity to a tire that has a looped coil similar to 54 embedded therein. For instance, coil 14 can take the form of a hand held wand attached to and exciter and detector assembly. By merely bringing the interrogator coil close to the surface of the tire at any point around its periphery, an electromagnetic coupling is established between the coil 14 and the transponder coil so that the energy and data interchange therebetween occurs along the lines of that described above.

Thus, a user can take a hand held wand and run it down a stack of tires so as to automatically record the actual identity of every tire in the stack. By well known data processing techniques, a complete and remarkably accurate inventory record of the tires is thereby available.

FIG. 6 illustrates an arrangement of elements for dynamically identifying vehicle tires while they are in use. It is a plan view of the outline of the tires of a truck relative to interrogator coils 56 and 58 each of which functions in a manner similar to interrogator coil 14 in FIG. 1. The vehicle tires in FIG. 6 are presumed to initially pass over leading edges 57A and 59A of interrogator coils 56 and 58, respectively. Tires 61-64 each have embedded transponders and are capable of responding to the interrogator coils within a respective transponder read zone 65-68 corresponding to the general area of ground engagement by the tire in which they are embedded.

The tire transponder is successfully read whenever and interrogator coil 56 or 58 edge is under the reading zone such as 65-68. The spacing 70 between the leading edge 57A or 59A and its corresponding trailing edge 57B or 59B for interrogator coils 56 and 58 is selected large enough so that both edges cannot intercept a reading zone concurrently.

Thus as tires 61 and 63 encounter the leading edges 57A and 59A of coils 56 and 58, transponders associated with zones 65 and

67 are read and the tires identified. Of course condition and/or environmental data is detectable from these transducers at the same time. Shortly thereafter, the transducer zones 66 and 68 encounter leading edges 57A and 59A so that data relating to tires 62 and 64 is communicated to the interrogator detector.

Note that a cross check of the previously read data is possible for each of these tires as they encounter the trailing edges 57B and 59B while leaving the area defined by interrogator coils 56 and 58. Similar readings are available for all the other tires 75-80 of the vehicle as it passes over coils 56 and 58. Furthermore, the system is bidirectional in that it can read the transponders equally well if the vehicle is traveling in a direction opposite arrow 72.

Interrogator coils such as 56 and 58 are placed in the roadway with wires at an angle, normally about 45^{o} to the direction of vehicle travel over interrogator coil wires. At the point coils 56 and 58 are initially encountered by tires 61 and 63, their companion tires 62 and 64 are still far enough away that their transponders do not respond at the same time as those for tires 61 and 62. The two edges of the loop are spaced far enough apart so that edges of the interrogator coil are not both close to the transponder wires at the same time.

Note that loop 58 can angle inwardly if desired so that the outer tires 61 and 64 are both read first and inner tires 62 and 63 read immediately thereafter. Note further that a single interrogator loop could achieve reading of all tires by extending its length completely across the vehicle roadway at an angle for accommodating the sequential reading of transponders.

By maintaining a memory profile of the vehicles and their tires, it is possible by this system to monitor where they as well as the condition of the tires. Of course the system is well suited for a remarkably wide variety of applications such as dynamically detecting the presence of stolen tires from interrogators embedded in the streets.

While the exemplary preferred embodiments of the present invention are described herein with particularity, those having normal skill in the art will recognize various changes, modifications, additions and applications other than those specifically mentioned herein without departing from the spirit of this invention.

CLAIMS

1. Apparatus for electronically identifying vehicle tir s comprising

a coil of at least one conductive wire loop,

signal generator means attached to said coil for responding to the presence of predetermined signals at said coil by transmitting a signal encoded with information uniquely identifying said signal generator means,

a vehicle tire having sidewall and tread surfaces, and

means securing said coil and said signal generator means to said tire with said coil positioned with the loop thereof in a relatively constant relationship relative to one of said tire surfaces.

2. Apparatus in accordance with claim 1 which further includes means for producing said predetermined signal for energizing said coil whenever said producing means is brought into proximity to said tire surfaces.

3. Apparatus in accordance with claim 2 which further includes means for detecting said encoded signal transmitted from said signal generator.

4. Apparatus in accordance with claim 3 which includes a second coil for receiving said encoded signal transmitted from said signal generating means and for introducing said received signals to said detecting means.

5. Apparatus in accordance with claim 4 wherein said second coil is positioned in a path of travel of said tire whereby said encoded signal transmission is retrievable dynamically.

6. Apparatus in accordance with claim 5 wherein said coil is positioned under said tread surface of said tire but with sufficient spacing therefrom so that said tire tread will wear away before said coil is exposed.

7. Apparatus in accordance with claim 5 wherein said second coil has spaced, generally parallel edges oriented at an angle relative to the direction of travel of said tire along said path.

8. Apparatus in accordance with claim 3 which includes means for sensing a condition associated with said tire, said signal generator means including means responsive to said sensing means for transmitting encoded information corresponding to said sensed tire condition in addition to said information uniquely identifying said signal generator means.

9. Apparatus in accordance with claim 1 wherein said signal generator means introduces said encoded signal to said coil for transmission.

10. Apparatus in accordance with claim 9 wherein said predetermined signal is at a first frequency and said signal generator means includes means for converting said predetermined signal to a different frequency for said encoded signal transmission whereby said encoded signal is transmitted concurrently with reception of said predetermined signal.

11. Apparatus in accordance with claim 10 wherein said coil and said signal generator are embedded in said tire with said coil in spaced relation to the tire bead in the inner periphery thereof.

12. Apparatus in accordance with claim 11 wherein said coil is positioned under said tread surface of said tire but with sufficient spacing therefrom so that said tire tread will wear away before said coil is exposed.

13. Apparatus for identifying vehicle tires which have sidewall and tread surfaces comprising

means for transmitting a signal at a first frequency,

a coil of at least one conductive wire formed in a generally circular loop for producing an output signal in response to energization thereof by said transmitting means signal,

means securing said coil with respect to at least one of the tire surfaces in a generally circular orientation with respect to the axis of the tire,

an electronic module secured to the tire and responsive to said coil output signal for shifting said first frequency signal to a second frequency signal, said module further including modulating means and coupling means with said modulating means encoding said second frequency signal with digital data uniquely corresponding to the identity of the associated tire, and said coupling means coupling said modulated second frequency signal to said coil for transmission therefrom, and

means separate from the tire for detecting said modulated second frequency signal.

14. Apparatus in accordance with claim 13 wherein said coil is embedded within the tire with a relatively constant spacing under the tire tread surface.

15. Apparatus in accordance with claim 14 wherein said coil is formed of multiple loops connected serially, and said detecting means includes a second coil having at least two spaced and generally parallel edges.

16. Apparatus in accordance with claim 15 wherein said second coil is positioned in a path of travel for the vehicle having the tire mounted thereon so that the tire tread surface passes over said coil edges in sequence.

17. Apparatus in accordance with claim 16 wherein said second coil is positioned in the path of travel with said edges angled relative to the direction of vehicle travel over the path whereby said detector can differentiate between said modulated second frequency signals from multiple tires.

18. Apparatus in accordance with claim 17 which further includes a pair of said second coils with each said second coil positioned for passage of tires thereover from respective sides of the vehicle.

19. Apparatus in accordance with claim 13 which includes means sensing conditions relative to the tire and for introducing signals to said module corresponding thereto, said module further including means for additionally modulating said second frequency signal with digital data corresponding to said sensing means output.

20. Apparatus in accordance with claim 13 wherein said coil and said module are both embedded within the tire.

21. A method for identifying vehicle tires comprising the steps of

attaching a loop of electrically conductive material to the tire in a generally circular configuration,

receiving signals of a first frequency whenever they are present in proximity to said loop of conductive material in the tire,

converting the received signal into a signal at a second frequency,

modulating said second frequency signals with digital information at least part of which corresponds to the tire identity, and

transmitting said modulated second frequency signals from the tire.

22. The method in accordance with claim 21 which includes the step of embedding said loop within the tire.

23. The method in accordance with claim 22 which includes the steps of

assembling components for providing said converting, modulating and transmitting steps into a module, and

connecting said module to said loop.

24. The method in accordance with claim 23 which includes the step of embedding said module within the tire.

25. The method in accordance with claim 22 which includes the steps of broadcasting a signal at said first frequency in proximity to the tire, and

detecting at a coil said transmitted second frequency signals transmitted from the tire.

26. The method in accordance with claim 25 which includes the step of demodulating the detected said second frequency signals to extract the information represented by the digital encoding thereof.

27. The method in accordance with claim 26 which includes the step of positioning said detecting coil in a path of travel of vehicles having tires with said second signal transmitting capability thereby permitting dynamic acquisition of tire identification information.

28. The method in accordance with claim 27 which includes the step of orienting said coil so that said detecting step is actuated by only one tire at a time despite mounting of multiple transmitting tires on a given vehicle.

AMENDED CLAIMS
[received by the International Bureau
on 09 July 1990 (09.07.90);
claims 1,3-5,8,9 and 21 amended, all other claims
unchanged (3 pages)]

1. Apparatus for electronically identifying vehicle tires comprising

a coil of at least one conductive wire loop,

signal generator means attached to said coil for responding to the presence of predetermined signals at said coil by transmitting a signal digitally encoded with information uniquely identifying said signal generator means,

a vehicle tire having sidewall and tread surfaces, and

means securing said coil and said signal generator means internally to said tire with said coil positioned with the loop thereof in a relatively constant relationship relative to one of said tire surfaces.

2. Apparatus in accordance with claim 1 which further includes means for producing said predetermined signal for energizing said coil whenever said producing means is brought into proximity to said tire surfaces.

3. Apparatus in accordance with claim 2 which further includes means for detecting said digitally encoded signal transmitted from said signal generator.

4. Apparatus in accordance with claim 3 which includes a second coil for receiving said digitally encoded signal transmitted from said signal generating means and for introducing said received signals to said detecting means.

5. Apparatus in accordance with claim 4 wherein said second coil is positioned in a path of travel of said tire whereby said digitally encoded signal transmission is retrievable dynamically.

6. Apparatus in accordance with claim 5 wherein said coil is positioned under said tread surface of said tire but with sufficient spacing therefrom so that said tire tread will wear away before said coil is exposed.

7. Apparatus in accordance with claim 5 wherein said second coil has spaced, generally parallel edges oriented at an angle relative to the direction of travel of said tire along said path.

8. Apparatus in accordance with claim 3 which includes means for sensing a condition associated with said tire, said signal generator means including means responsive to said sensing means for transmitting encoded information corresponding to said sensed tire condition in addition to said digitally encoded information uniquely identifying said signal generator means.

9. Apparatus in accordance with claim 1 wherein said signal generator means introduces said digitally encoded signal to said coil for transmission.

10. Apparatus in accordance with claim 9 wherein said predetermined signal is at a first frequency and said signal generator means includes means for converting said predetermined signal to a different frequency for said digitally encoded signal transmission whereby said digitally encoded signal is transmitted concurrently with reception of said digitally predetermined signal.

11. Apparatus in accordance with claim 10 wherein said coil and said signal generator are embedded in said tire with said coil in spaced relation to the tire bead in the inner periphery thereof.

21. A method for identifying vehicle tires comprising the steps of

attaching a loop of electrically conductive material to the tire in a generally circular configuration,

receiving signals of a first frequency whenever said first frequency signals are present in proximity to said loop of conductive material in the tire,

converting the received signal into a signal at a second frequency,

modulating said second frequency signals with digital information at least part of which corresponds to the tire identity, and

transmitting said modulated second frequency signals from the tire.

22. The method in accordance with claim 21 which includes the step of embedding said loop within the tire.

23. The method in accordance with claim 22 which includes the steps of

assembling components for providing said converting, modulating and transmitting steps into a module, and

connecting said module to said loop.

24. The method in accordance with claim 23 which includes the step of embedding said module within the tire.

25. The method in accordance with claim 22 which includes the steps of broadcasting a signal at said first frequency in proximity to the tire, and

detecting at a coil said transmitted second frequency signals transmitted from the tire.

STATEMENT UNDER ARTICLE 19

The present invention is a combination of apparatus and processes for uniquely allowing identification of vehicle tires.

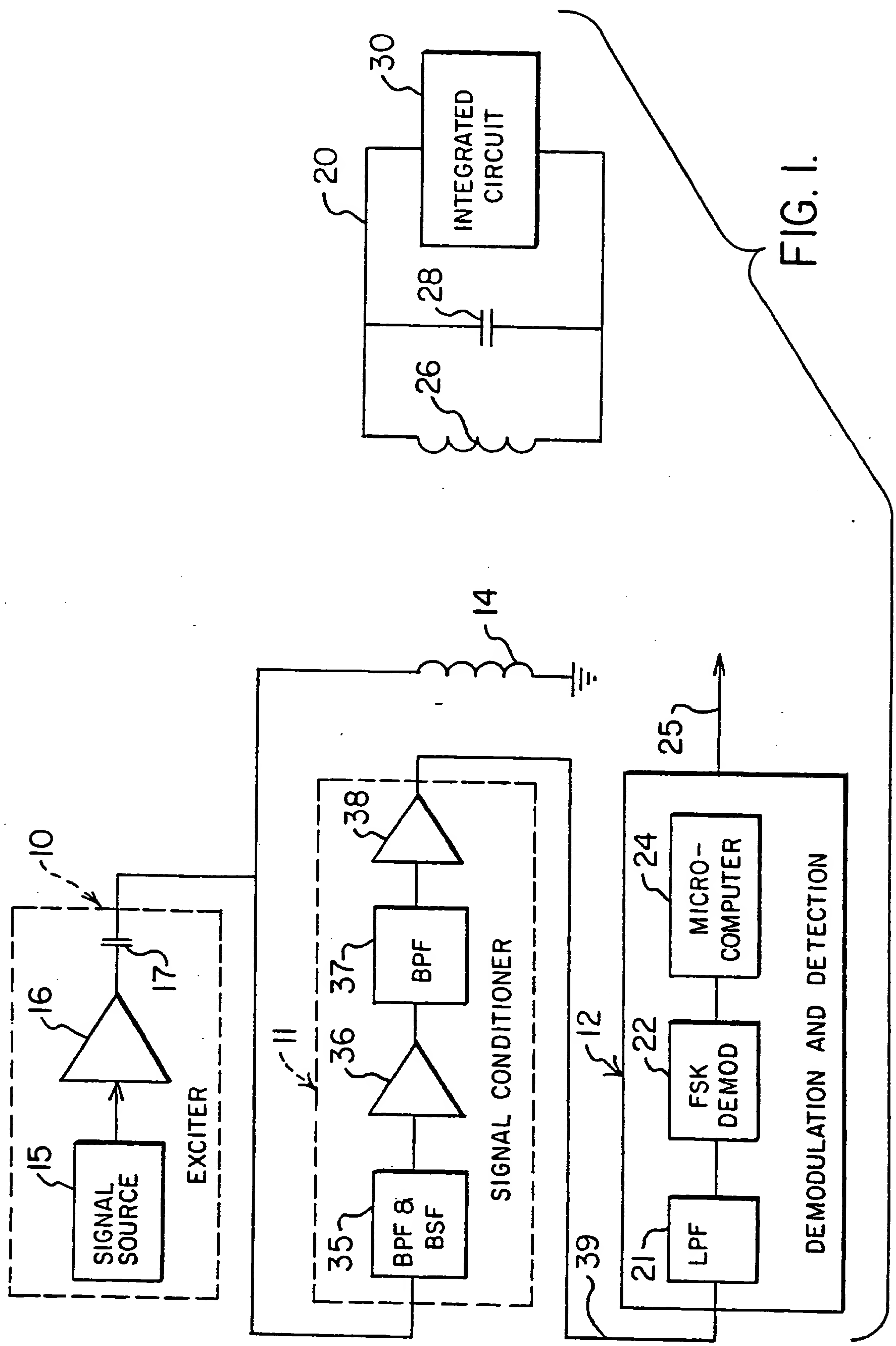
The invention as recited in amended claim 1, recites a structure relationship; include a coil which has at least one loop of wire, along with a signal generator attached to this coil, so as to respond to the presence of predetermined signals by transmitting a digitally encoded signal. The digital encoding includes information that uniquely identifies the signal generating means and thus the tire containing it. The vehicle tire includes sidewalls and tread surfaces with the coil and signal generator secured relative to the tire so that the coil is positioned with the loop thereof in a relatively constant relationship with respect to the tire surfaces.

Claim 3, and 4 as amended depend ultimately from amended claim 1. These claims recite with greater specificity the structure for energizing the coil by bringing it into proximity to the tire surfaces, the detection of the digitally encoded signal from the tire signal generator (claim 3), as well as the reception and detection of the digitally encoded signal (claim 4).

Claim 5 as amended depends from claim 1 via claim 4 and relates to the positioning of the detector coil in the path of travel of the tire, for dynamically detection of the digitally encoded signal transmission.

Claim 8 as amended is directed to apparatus which includes an arrangement for sensing a condition associated with the tire, with the signal generator including means responsive to this sensing for transmitting encoded information in addition to the digitally encoded information that uniquely identifies the signal generator and thus the tire.

The method of vehicle tire identification contained in claim 21 as amended, is concerned with the process of attaching the loop of conductive material to the tire in a circular configuration and receiving signals of the first frequency whenever these first frequency signals are present in proximity to the conductive material loop. After converting that receive signal into a second frequency signal, the second frequency is modulated with digital information at least part of which corresponds to the tire identity followed by transmitting of this second frequency modulated signal from the tire.


INTEGRATED CIRCUIT
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20
28
26
14
10
16
17
15
SIGNAL SOURCE
EXCITER
11
35
BPF & BSF
36
37
BPF
38
SIGNAL CONDITIONER
25
12
39
21
LPF
22
FSK DEMOD
24
MICRO-COMPUTER
DEMODULATION AND DETECTION

FIG. 1.

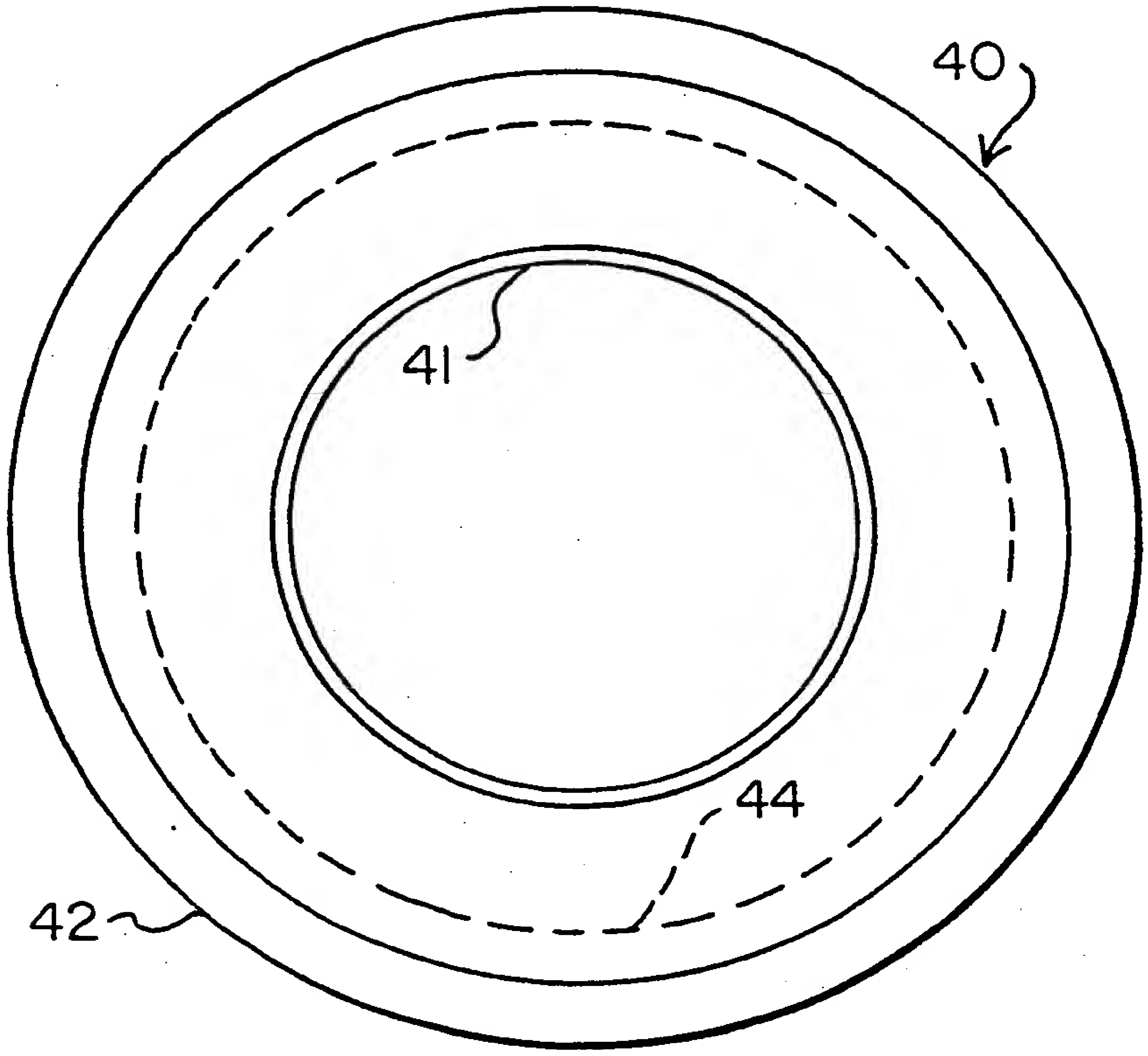


FIG. 2.

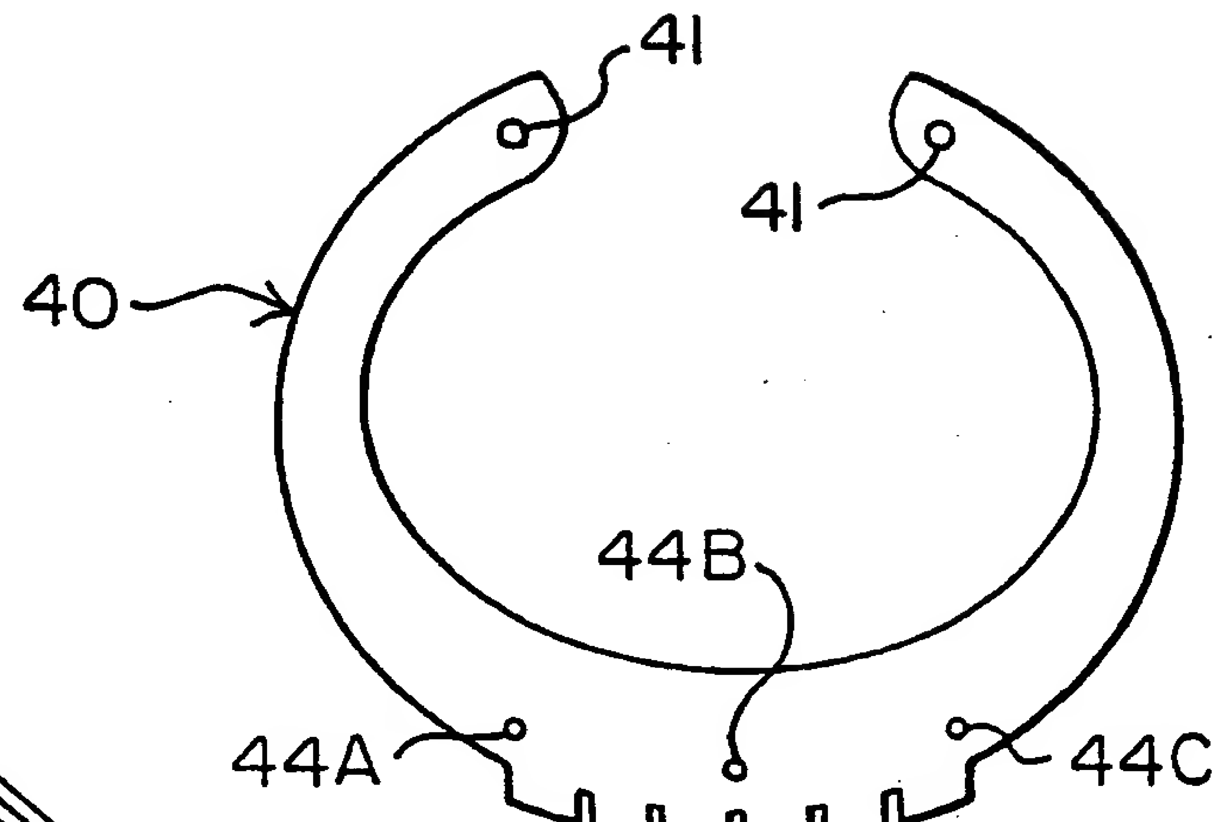


FIG. 3.

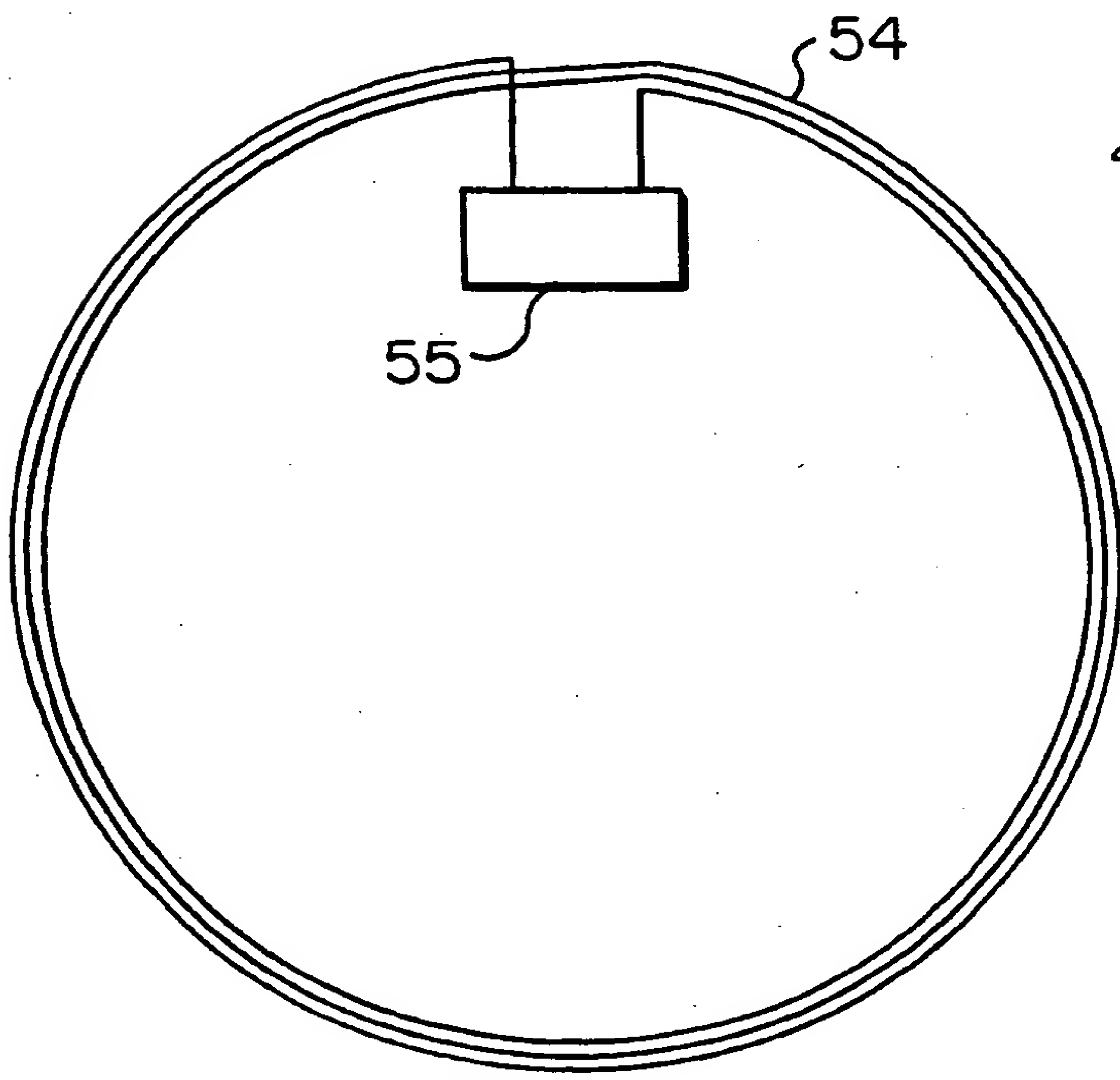
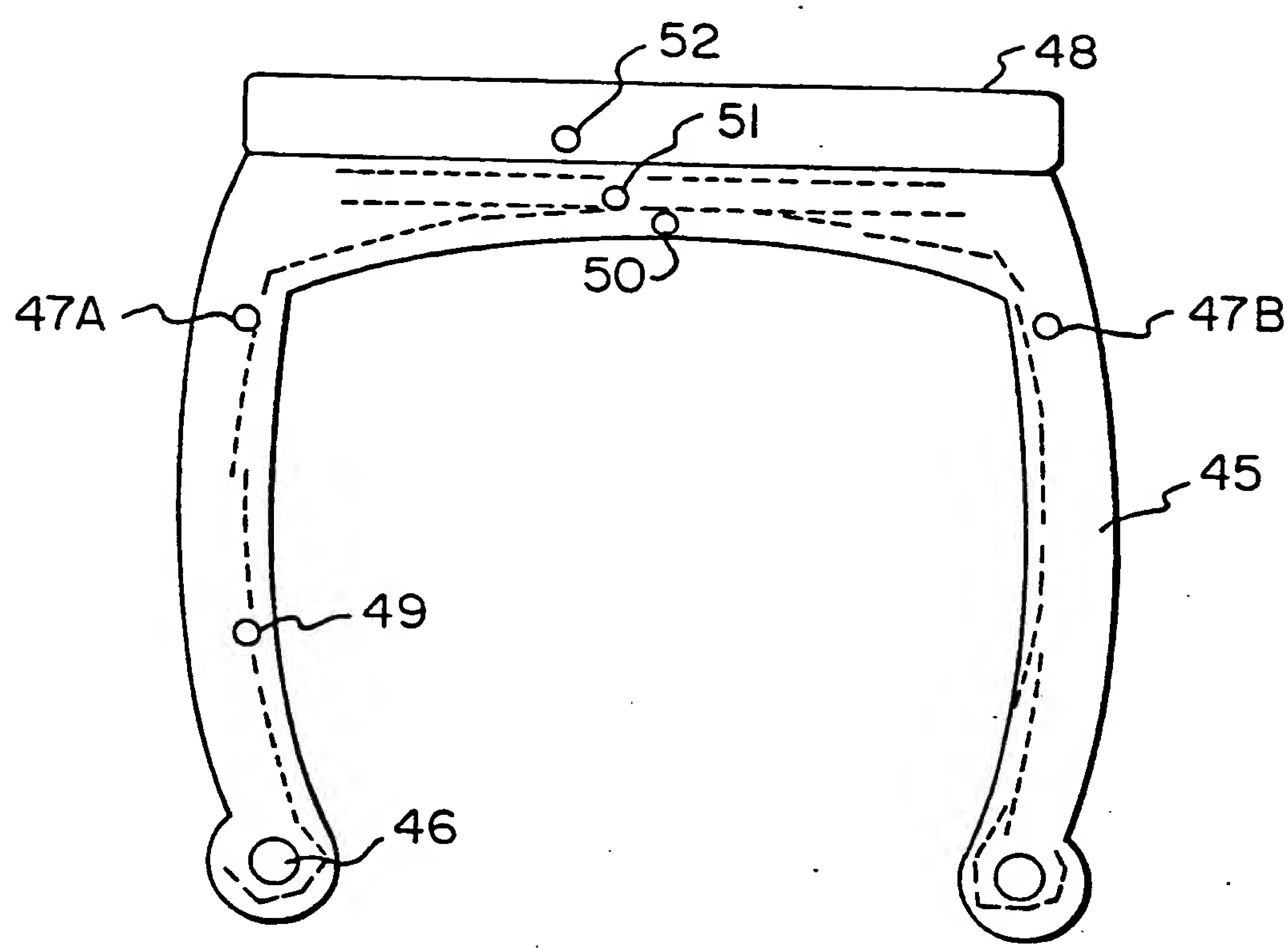


FIG. 5.


52
48
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47A
47B
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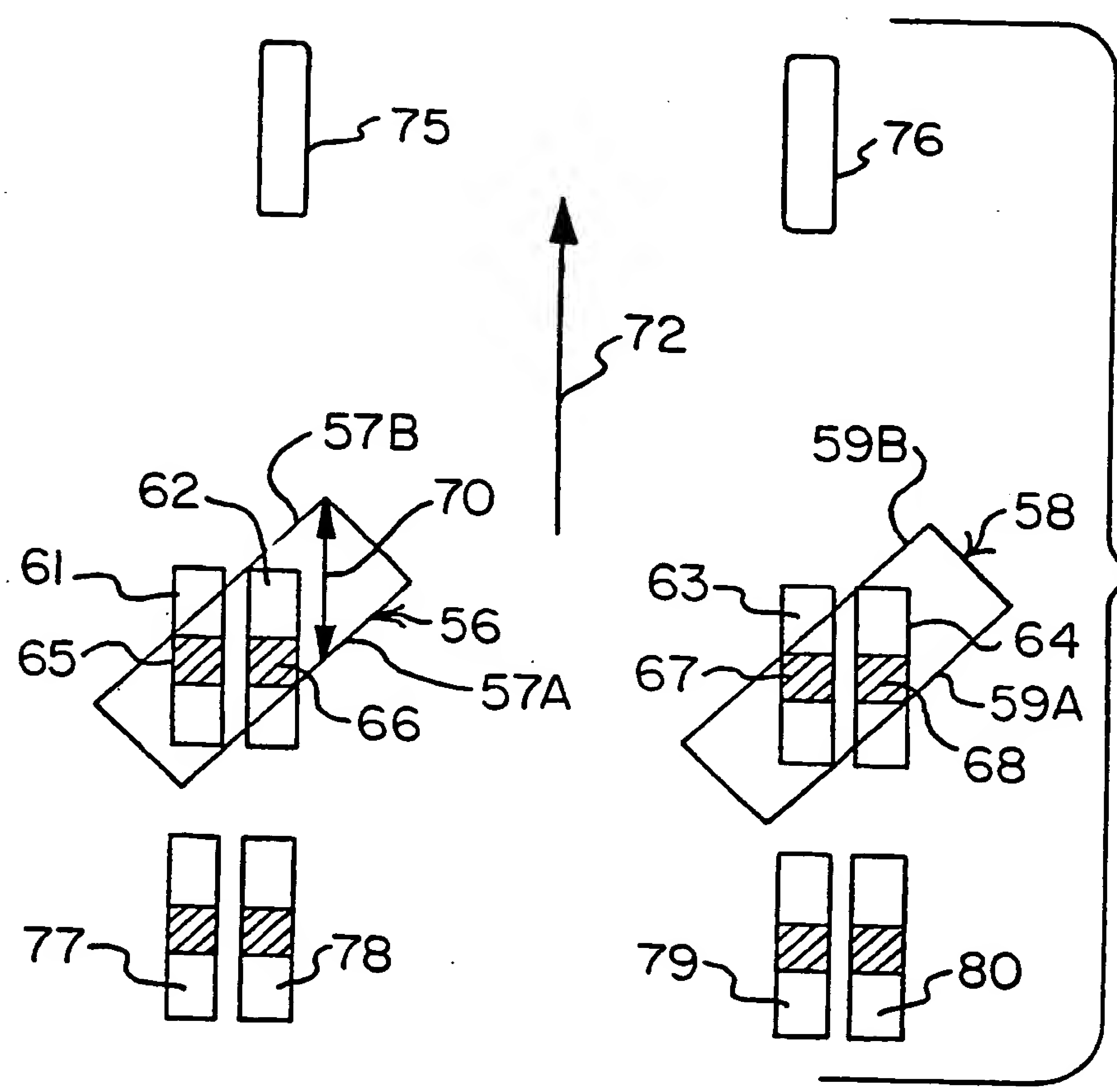
49
46

FIG. 4.


75
76
72
57B
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59B
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57A
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59A
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FIG. 6.

ERNATIONAL SEARCH REPO

International Application No. PCT/US90/01754

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC
IPC(5) H04Q 7/00
U.S. CL.: 340/825,540

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
U.S. CL.	73/8, 146, 146.4, 146.5 342/51 324/66 152/154.2 340/825.54, 825.55, 505, 445, 447, 448, 870.16, 870.31

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category *	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No. 13
Y	US, A, 3,770,040 (De CICCO) 06 November 1973, (See column 4, lines 36-46)	1-28
Y	US, A, 4,578,992 (GALASKO ET AL.) 01 April 1986 (See entire document)	1-28
Y	US, A, 4,588,978 (ALLEN) 13 May 1986, (See entire document)	1-28
Y	US, A, 4,730,188 (MILHEISER) 08 March 1988, (See column 1, lines 9-15)	1-28

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
05 MAY 1990	04 JUN 1990
International Searching Authority	Signature of Authorized Officer
ISA/US	ULYSSES WELDON

Form PCT/ISA/210 (second sheet) (Rev.11-87)